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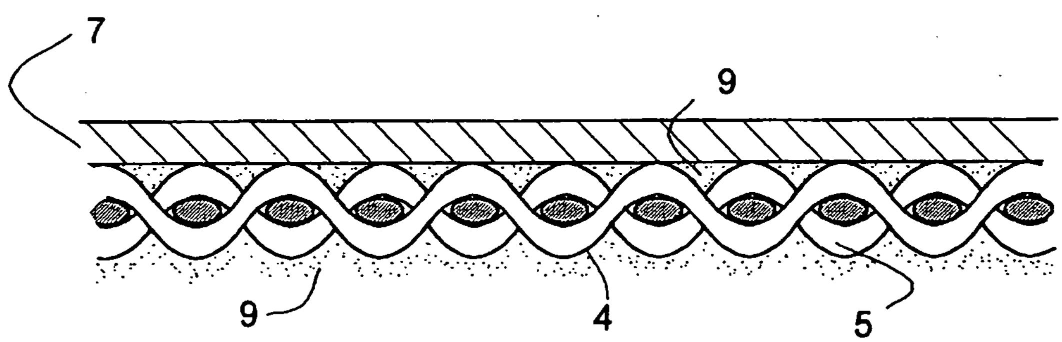

(57) Abstract: The invention concerns a flexible composite membrane for sound dampening, light transmission and radiant heat control. The composite membrane comprises a flexible fibrous reinforcement layer, a polymer deposition layer covering the reinforcement layer, and a low emissivity layer adhered to the polymer deposition layer.

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COMPOSITE MEMBRANE FOR CONTROL OF INTERIOR ENVIRONMENTS

This application claims the benefit of U.S. Provisional Application No. 60/211882 filed June 15, 2000.

FIELD OF THE INVENTION

This invention relates to flexible composites that are used in the fabrication of architectural structures. In particular, the invention concerns a flexible composite membrane for control of sound, light and heat in interior environments of such architectural structures.

BACKGROUND OF THE INVENTION

Structural and civil engineers have used plate glass in the cladding of buildings for many years. Plate glass provides a high level of sunlight transmission to the interior of the building, thus decreasing the need for interior lighting and increasing the open feel of the interior space. High visible light transmission is accompanied by high infrared or heat transmission, which in turn can produce uncomfortably hot interior spaces (or alternatively, excessive cooling costs). A typical traditional procedure to counteract the high infrared transmission of glass, is to coat plate glass with a thin deposited layer of material known to reduce the emissivity of the glass and thereby reduce the heat gain within the enclosed space. The thin deposited layer, which usually includes metals such as aluminum and gold, can be quite fragile and must be protected from oxidation and from abrasion or flexing that can remove the deposited layer from the substrate. Oxidation, or removal of the deposited layer through abrasion or flexing increases the emissivity of the material and reduces the effectiveness of the treatment.

As an alternative to glass plate, flexible membrane materials have also been used in structures for many years. High strength, weatherable membranes capable of bearing long term, dynamic and structural loads have been used as the outer shell of permanent buildings.

Conventional flexible membrane materials for modern permanent architectural structures usually include coatings to improve fire and weather resistance. Some of these coated composite materials such as ULTRALUX® Architectural Membrane and

SHEERFILL® Coated Glass Fabric, both manufactured by Saint-Gobain Performance Plastics Corporation (Wayne, New Jersey, formerly Chemfab Corp., Merrimack, New Hampshire) have been capable of transmitting substantial amounts of light through the myriad of tiny gaps between the yarns of the membrane fabric (*i.e.*, the so called windows in the woven fabric).

Flexible composites such as FABRASORB® Acoustical Fabric (also by Saint-Gobain Performance Plastics Corporation, formerly Chemfab Corp) have also been developed for sound dampening inside buildings . These open mesh membranes minimize the sound reverberation within a space while still allowing light to be transmitted through the membrane.

Low emissivity (also referred to as "Low E") coatings have been deposited on flexible substrates such as polyimide or fluorinated ethylene propylene copolymer ("FEP") films and used in capacitors or passive thermal control in spacecraft. Even so, nothing in the prior art has considered or suggested depositing Low E coatings on flexible composites for incorporation into architectural structures. This is primarily because handling and in-use loads were thought to be too destructive to the continuity of the low emissivity surface.

Thermal insulation of large spaces has been accomplished by placing 'glass wool' insulation between a liner of flexible membrane such as FABRASORB® Acoustical Fabric and an outer membrane material or by passing air between the liner and the outer fabric. Heat control is thus achieved through the principles of conductive or convective heat transfer. These methods suffer from the draw backs that the insulation layer can reduce visible light transmission and that circulating air heating and ventilation systems are often mechanically complex and require periodic operating and maintenance labor and replacement parts. In addition, forced air systems consume energy and generate noise.

It would be desirable to provide a flexible membrane that has good light transmission and sound dampening characteristics and additionally is capable of controlling the internal environment of a building structure through radiant heat control. It is also desired to have a flexible, sound, light and radiant heat controlling membrane which further has strength and durability suitable for the membrane to integrate with the load bearing structure of a permanent building or other architectural construct.

SUMMARY OF THE INVENTION

The invention concerns a flexible composite membrane primarily as a construction material in architectural structures for sound dampening, light transmission and radiant heat control. The composite membrane comprises a flexible fibrous reinforcement layer; a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4, in which the composite membrane is flexible.

The composite membrane of the invention has a number of useful qualities and benefits not heretofore achieved in the prior art. The membrane is strong and flexible and the low emissivity layer is extremely well-bonded to the polymer deposition layer. As such, the membrane may be used in structural architectural applications as an integral part of the building's environmental (lighting, HVAC and sound) control system. That is, the membrane can be utilized as a component in one or more of the interior or exterior walls, ceilings, windows, roofs, partitions, awnings and the like of buildings or enclosures. The low emissivity of the composite membrane renders it particularly useful in attenuating radiant heat transmission to decrease hot spots within an enclosed environment, which consequently minimizes cooling costs. The novel composite membrane can also provide beneficial sound and light transmission characteristics, *i.e.*, low sound reflectance and high light transmission.

According to this invention there is also provided an architectural structure comprising a flexible composite membrane for sound dampening, light transmission and radiant heat control, the composite comprising:

a flexible reinforcement layer;

a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and

a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4.

Still further there is provided a method of controlling sound, light and radiant heat transmission in an architectural structure having component structural members, the method comprising the steps of

(a) providing a flexible composite membrane comprising:

a flexible reinforcement layer;

a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and

a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4,

(b) deploying at least one component member which comprises the composite membrane.

Additionally this invention provides a method of making a flexible composite membrane for sound dampening, light transmission and radiant heat control, comprising: the steps of

providing a flexible fibrous reinforcement layer having yarns defining windows aggregating about 30-50 % of the area of the reinforcement layer,

laminating a polymer deposition layer defining opposite first and second sides to the reinforcement layer such that the first side of the polymer deposition layer is positioned adjacent to the reinforcement layer,

depositing a low emissivity layer having an emissivity of less than about 0.4 onto the first side of the polymer deposition layer, thereby exposing the low emissivity layer through the windows of the polymer deposition layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a cross section of a partial composite membrane according to an embodiment of the invention.

Fig. 2 shows a perspective view of a woven fibrous reinforcement used in the composite membrane illustrated in Fig. 1.

Fig. 3A shows a cross section of a first embodiment of the composite membrane according to the invention.

Fig. 3B shows the first embodiment of the composite membrane viewed from the bottom of Fig. 3A.

Fig. 3C shows a cross section of a second embodiment of the composite membrane according to the invention.

Fig. 3D shows the second embodiment of the composite membrane viewed from the bottom of Fig. 3C.

Fig. 4 shows a cross section of a third embodiment of the composite membrane according to the invention.

Fig. 5 shows a cross section of a structure employing a composite membrane according to the invention.

Fig. 6A is a photograph showing a top view of a composite membrane according to this invention in an unstressed state.

Fig. 6B is a photograph showing a top view of a composite membrane according to this invention after being stressed in tension applied in the plane of the membrane.

DETAILED DESCRIPTION

The main function of the flexible reinforcement layer is to provide mechanical strength to the composite membrane. Although the use of the novel membrane is not limited to applications of any particular size, it is contemplated that the membrane will be employed in expansive architectural structures, such as roofs for stadiums, arenas, vehicle tunnels, museums, theaters, concert and exposition halls, tents, walkways and shed covers. Hence, substantial stresses can be applied to the membrane in use. The flexible reinforcement layer is primarily responsible for maintaining the shape and dimensional stability of the membrane under such stressful conditions. In service the composite membrane may be called upon to contact other stationary or moving members of an architectural structure. The composition and form of the flexible reinforcement layer also can be selected to impart tear, flex fatigue, abrasion, puncture resistance and similar properties that affect durability of the composite membrane. The extent to which the composite membrane has need for each of these properties depends largely on the nature of the end use application. Accordingly, the desired durability performance of the membrane should be considered in the selection of the composition and form of the flexible reinforcement layer.

The material of the reinforcement layer can be selected for visible light filtering and/or sound dampening characteristics. That is, this material can range from substantially visible light transparent to opaque, and the reinforcement layer thickness and texture can be chosen to selectively dampen the transmission of sound. Visible light filtering can be accomplished by selecting a material composition which has natural opacity from clear, *i.e.*, nearly completely light transparent, to fully opaque. Alternatively, the light transmission characteristics of the reinforcement layer material can be achieved by compounding into

intrinsically high transmission material opaque pigments or visible light blocking additives in preselected amounts effective to provide the composite membrane with a desired degree of light blocking capacity. One of ordinary skill in the art will be able to choose the composition and form of the flexible reinforcement layer based on these criteria and the teachings of this disclosure without undue experimentation.

The flexible reinforcement layer can be constructed in a variety of forms, including fibrous material, such as woven and non-woven fabrics, and non-fibrous material, such as porous and perforated films and combinations thereof. By "fibrous material" is meant an assembly formed from yarn. "Yarn" means one or more filaments and thus encompasses monofilament and multifilament elements. Diverse conventional woven fabrics and non-woven fabrics such as spunbonded and meltblown filament webs can be used. For yarn-based reinforcement layer fabrics, filament diameter and weave pattern can be selected to suit the mechanical properties and light and sound transmission characteristics called for by each end-use application. Various fibrous materials suitable for use in this invention are disclosed in U.S. Patent No. 4,770,927, assigned to Saint-Gobain Performance Plastics Corporation, formerly Chemical Fabrics Corporation) the entire disclosure of which is hereby incorporated by reference herein. In general, filament and yarn dimensions utilized in conventional fabric arts can be utilized in this invention. Preferably, yarn diameter should be within the range of about 150 - 1500 micrometers (6-60 mils), more preferably about 250-1000 micrometers (10-40 mils), and most preferably about 350-760 micrometers (14-30 mils). The reinforcement layer of non-fibrous material can be a perforated film, for example.

The reinforcement layer can consist of a single woven or non-nonwoven fabric or it can include multiple overlaid strata of one or both fabric types. When the reinforcement layer comprises multiple strata, preferably the component strata are attached to each other by conventional means. For example, the strata can be knitted, interwoven, stitched, or punched together or affixed by an adhesive to form the multi-strata reinforcement layer. The adhesive can be a thermal bond, such as a hot melt adhesive, chemical bond or a combination thereof.

In a preferred embodiment, the reinforcement layer is a substantially open weave fabric. The term "substantially open weave" means that the aggregate open area of the windows between the yarns in the plane of the fabric constitutes a substantial fraction of the total

area of the fabric, that is, the product of the length and the width, of the reinforcement layer. A large open area of the reinforcement layer increases both sound and light transmission. The open area also provides a conduit through which the polymer deposition layer can bond to the low emissivity layer in a particularly preferred embodiment described in greater detail below. In a much preferred embodiment, the aggregate open area is about 30-50% of the total area.

In many applications the composite membrane will be used primarily for its advantageous properties of sound and light transmission with low heat transfer. In such circumstances, the material of the fibrous reinforcement layer should be selected mainly for its ability to maintain structural integrity of the polymer deposition layer and the low emissivity layer in the composite membrane. It is envisioned that the composite membrane may also be used as a load-bearing member for a structure. In that case, the reinforcement should be selected and constructed to withstand the loads under anticipated end-use application conditions.

Many materials can be used for the flexible fibrous reinforcement layer. Representative materials include, poly-(*m*-phenyleneisophthalamide) Nomex® synthetic fiber, poly-(*p*-phenyleneterephthalamide) Kevlar® synthetic fiber, Lycra® spandex polyurethane elastomeric fiber, all from DuPont, Wilmington, Delaware, polyalkylene, such as polypropylene fiber or Spectra® polyethylene fiber from Allied-Signal Corporation, Morristown, New Jersey, polyamide (sometimes referred to as nylon polymer), polyester, glass or carbon fiber and blends of these.

The polymer deposition layer may cover one or both sides of the reinforcement layer. The polymer deposition layer may take the form of a coating or a film and may comprise one or more layers of coatings and/or films. The polymer deposition layer typically has a thickness of about 10-50 micrometers to render it sound and light transmissive. For so-called "liner" end-use applications, any polymer composition that can be formed into a film or coating of the desired thickness and adhered to the reinforcement layer can be used for the polymer deposition layer. By the term "liner" is meant a type of application in which the composite membrane is shielded from harsh climatic conditions such as wind, humidity, outdoor temperature fluctuations and direct impingement of solar and atmospheric radiation when deployed. For example, a composite membrane inside a building, for example suspended from the building's ceiling, is a liner application. For

outdoor applications, the deposition layer polymer should also be suitably weather resistant. Weather resistance can be improved by compounding certain common weather resistance enhancing additives into the deposition layer polymer as is well known in the art.

To comply with codes associated with certain structural applications, the composite membrane should be fire resistant. These properties may be achieved by using fire resistant materials for the reinforcement and polymer deposition layers. Many fluoropolymers exhibit a suitable degree of fire resistance. Consequently, the polymer deposition layer preferably comprises a fluoropolymer. The term "fluoropolymer" means a polymer or copolymer comprising at least one fluorine-substituted monomer. Suitable fluoropolymers include polytetrafluoroethylene (PTFE), fluorinated ethylene propylene copolymer (FEP), perfluoroalkoxy resin (PFA), polyperfluorovinylether, polychlorotrifluoroethylene (CTFE), polyvinylidene fluoride (VF2), polyethylenechlorotrifluoroethylene (ECTFE), polyethylene-tetrafluoroethylene (ETFE), polyvinylfluoride (PVF) and blends thereof. A non-fluoropolymer, such as polyvinylchloride (PVC), polyvinylalcohol (PVA), and blends thereof. Non-fire resistant materials can be blended with one or more fire resistant additives in amounts effective to render the blends suitably fire-resistant for use in this invention. Such additives are well known in the art. Blends of fluoropolymer and non-fluoropolymer can be used.

The low emissivity layer includes a material having an emissivity of less than about 0.4. The term "emissivity" means the ratio of the radiation emitted by a body to the radiation that which would be produced by a perfect blackbody radiator of the same temperature in the same environment. Low emissivity materials are known in the art and include, for example, aluminum, gold, indium tin oxide, chrome, brass, copper, nickel, mild steel, stainless steel, lead, platinum, inconel, silver, tantalum, tungsten, germanium, molybdenum, or rhodium. Some low emissivity materials are highly chemically reactive with substances that are likely to be present in the environment in which the composite membrane will be deployed. Such reactive low emissivity materials should utilize a protective coating to shield them from exposure to the environment to minimize occurrence of undesirable reactions, such as oxidation. The protective coating may comprise a variety of materials, for example, acrylic polymer or partially crystalline or amorphous homopolymers or copolymers comprising tetrafluoroethylene, vinylidene fluoride, or chlorotrifluoroethylene.

The term "flexible" has heretofore been used mostly to describe the "flexible reinforcement layer." It is contemplated that in some uses the composite membrane can be bent around objects, draped from supports, e.g., in catenary fashion, twisted out of planar configuration or otherwise subjected to bending deformation without breaking. Therefore, not merely the reinforcement layer, but rather the whole composite membrane should exhibit flexibility. In connection with fabrics, the term "compliance" is typically used to identify the flexibility property of a material and may be considered to be interchangeable with the term "flexibility" herein. It should thus be understood that the materials selected for each component of the membrane should enhance the compliance of the composite membrane.

The invention can be further understood with reference to the figures, in which like reference numerals denote like parts. Fig. 1 shows a partial composite membrane 1 according to the invention. The composite membrane 1 includes a flexible reinforcement layer 5, which in the embodiment disclosed in Fig. 1 is a woven fibrous fabric (shown in Fig. 2). A polymer deposition layer, which preferably comprises a fluoropolymer film 7, is bonded to one side of the flexible fibrous reinforcement 5.

As seen in Figs. 3A, 3C and 3D, a low emissivity layer 9 having an emissivity of less than about 0.4 is deposited on the polymer deposition layer. The deposition may be accomplished in a number of known ways, including evaporative, sputtered or ion beam assisted deposition. In one embodiment, the low emissivity layer 9 is composed of aluminum. The low emissivity layer 9 can be deposited directly over the fluoropolymer film 7 as illustrated in the embodiment of Fig. 3A. As seen in a different embodiment depicted in Figs. 3C and 3D, the low emissivity layer can be deposited on the opposed surface 4 of the flexible fibrous reinforcement 5 and bonded to those portions of the fluoropolymer film 7 that bridge the windows 13 (See Figs. 2, 3B and 3D) of the woven open weave fabric.

Referring to Fig. 4, in an another embodiment, two low emissivity layers 17 and 19 are bonded to both sides of the flexible fibrous reinforcement 5 that previously had its upper surface bonded to a fluoropolymer film 7.

In Fig. 5, the composite membrane of the invention is shown in application. Fig. 5 shows a structure 50 (for example, a dome) employing a number of composite membranes of the invention. The structure typically includes cross beams, such as beams 21 and 23 to

provide structural support for the membranes which together create an enclosed space "A" below. As is known in the art, an architectural composite 30 is disposed between the beams to provide support and to enclose the space A. A composite membrane 1 according to the invention is then connected to the architectural composite 30 in a slightly draped loose fitting manner on the interior of the structure. The loose fit attachment of the composite membrane 1 to the architectural composite 30 ensures that the composite membrane is minimally subjected to any loads or stress experienced by the architectural composite 30.

Alternatively, the composite membrane of the invention may actually be employed as the structural architectural composite. In this case, the membrane will provide the advantageous benefits concerning light and sound transmission without inordinate heat transfer, but the membrane will also provide the structural support required for the application. Typically tensile stress applied to the composite membrane under such load-bearing conditions will be at least about 35 N/cm (20 pounds per linear inch "pli"). The adhesion of the low emissivity layer to the fluoropolymer is so high that the layer will remained adhered to the fluoropolymer when the membrane is subjected to various loads. The adhesion between the low emissivity layer and fluoropolymer is actually higher than the internal cohesion of the low emissivity material itself. In many cases, if the composite membrane is subjected to a high stress, the low emissivity material may crack, but it will not flake off from the polymer deposition layer. While the cracking may form small gaps that will increase the overall emissivity of the material, this increase is nonetheless minimized because the low emissivity material remains adhered to the polymer deposition layer.

This invention is now illustrated by examples of certain representative embodiments thereof, wherein all parts, proportions and percentages are by weight unless otherwise indicated. All units of weight and measure not originally obtained in SI units have been converted to SI units.

EXAMPLE 1

A 0.424 kg/m^2 (12.5 ounce per square yard "osy") plain weave fabric of fiberglass ECG150 4/2, 13 x 12 yarns/inch count (Saint-Gobain Performance Plastics Corporation, formerly Chemfab Corp) 50% open weave area was impregnated with a combination of

Fluon® AD1H PTFE (Asahi Glass Fluoropolymers USA Inc., Bayonne, New Jersey, formerly Imperial Chemical Industries, Inc.) as an aqueous dispersion, 60% solids) and methylphenyl silicone oil (ET-4327 obtained from Dow Corning as an aqueous emulsion, 35% solids). The coating was applied by dipping, drying and fusing in a three zone coating tower with drying zone temperatures of approximately 38°C (100 °F), baking zone temperatures of approximately 343°C (650° F) and a sintering zone temperature of 360 to 371°C (680 to 700 °F). The coating contained 93 parts PTFE and 7 parts methylphenyl silicone. The applied weight of this coating was 0.020 kg/m^2 (0.6 osy). Only the yarns of the fabric were coated, the windows remained substantially open. Drying, baking and sintering times were approximately 2 minutes, 1 minute and 2 minutes respectively.

A second PTFE coating, totaling another 0.020 kg/m^2 (0.6 osy), was applied from AD1H. Drying, baking and sintering times and temperatures were similar to the first coating.

A third coating of Teflon® FEP T121A obtained from DuPont as an aqueous dispersion, 55% solids) was applied and dried, baked and sintered. Drying zone temperatures were 121°C (250 °F), baking was 204°C (400 °F) and sintering temperatures were 316°C (600 °F). Drying, baking and sintering times were 1 minute, 30 seconds and one minute respectively. Again 0.020 kg/m^2 (0.6 osy) of coating were deposited on the fabric.

This coated fabric was laminated to a 25.4 micrometer (1 mil) Teflon® FEP film (obtained from DuPont, type A) so that the film is attached to only one face of the coated fabric. To achieve this lamination, the film and fabric were passed between four sets of platens pairs (one on top and one below the material) and alternating with nipped rolls. The temperatures of the platens were 177, 232, 274 and 288°C (350, 450, 525 and 550 °F) and the nips were run with no pressure on the first nip and light pressure on the second, third and fourth nip. Residence time in each thermal zone was about 30 seconds.

This laminated intermediate had the following properties:

Weight	0.542 kg/m^2 (16.0 osy)
Thickness	566 micrometers (22.3 mils)
Tensile	830 x 520 N/cm (474 x 297 pounds force per linear inch "pli")
Tear	236 x 196 N (53 x 44 lbs force)
Elongation	0.8 x 5.8 %

Transmission 29.4 %

These properties were determined according to known tests and standards as follows:

weight -	ASTM D4851-88
thickness -	ASTM 4581-88
tensile (breaking) strength -	ASTM 4581-88'
Trapezoidal tear -	ASTM 4581-88
Transmission -	E424-71
Emissivity -	ASTM E408, Method A

Elongation - was determined by a method similar to ASTM D1682 except that the cross head speed used is 1.3 cm/min. (0.5 inches / min) and the elongation is calculated where the sample reaches a load of 70 N/cm (40 lbs/in).

A low emissivity layer in the form of an aluminum coating (100-400 Angstroms) was deposited by vacuum deposition via evaporation on the face of the fabric opposite to the face coated with the FEP film. The aluminum coating consequently adhered to both the third FEP coating on the fabric and to the FEP film in the area where the film bridged the windows of the open weave fabric. The FEP surfaces were pretreated to make them particularly receptive to the deposition of the aluminum coating. Several methods are known for pretreating the fluoropolymer surface to render it receptive to the deposition of the low emissivity material. Such methods useful for rendering FEP receptive to the deposition of aluminum include, for example corona treatment or low energy plasma treatment. The transmission of the final composite was 12.5 % and the emissivity of the aluminized face was 0.32.

EXAMPLE 2

The composite membrane of Example 1 was provided with an acrylic overcoat over the aluminum coating low emissivity layer. The acrylic overcoat serves as a protective finish to prevent scratching and oxidation of the aluminum coating.

EXAMPLE 3

The composite membrane of Example 1 was provided with an overcoat of polyvinylidenefluoride over the aluminum coating low emissivity layer. Similar to Example 2, the overcoat serves as a protective finish.

EXAMPLE 4

A 0.424 kg/m^2 (12.5 osy) plain weave fabric of fiberglass ECG150 4/2, 13 x 12 yarns/inch count (Saint-Gobain Performance Plastics Corporation formerly Chemfab) 50% open weave area was impregnated with a combination of Fluon® PTFE (AD1H as an aqueous dispersion, 60% solids) and methylphenyl silicone oil (ET-4327 obtained from Dow Corning as an aqueous emulsion, 35% solids) was applied by dipping, drying and fusing in a three zone coating tower with drying zone temperatures of approximately 38°C (100 °F), baking zone temperatures of approximately 343°C (650° F) and a sintering zone temperature of 360 to 371°C (680 to 700 °F). The coating contained 93 parts PTFE and 7 parts methylphenyl silicone. The applied weight of this coating was 0.020 kg/m^2 (0.6 osy). Only the yarns of the fabric were coated, the windows remaining substantially open. Drying, baking and sintering times were approximately 2 minutes, one minute and two minutes respectively.

A second coating, totaling another 0.020 kg/m^2 (0.6 osy), was applied from AD1H. Drying, baking and sintering times and temperatures were similar to the first coating.

Coatings three and four were made with CF6844 (966 parts Fluon® PTFE AD1H, 32 parts Teflon® FEP T121A and 2 parts Silwet L77 obtained from Witco Corp.). Drying, baking and sintering zone temperatures were 121°C (250 °F), 204°C (400 °F) and 354°C (670 °F) respectively and dwell times were about one minute in each zone. The coating weight of this layer was 0.325 kg/m^2 (9.6 osy) and the coating bridged all of the open windows of the woven fabric.

A topcoat of Fluon® FEP (T121A) was applied at .013 kg/m^2 (0.4 osy). Drying, baking and sintering times and temperatures were similar to coatings three and four.

The physical properties of this intermediate were as follows:

Weight	0.827 kg/m^{2}24.4 osy
Thickness	713 micrometers (28.1 mils)
Tensile	1050 x 866 N/cm (600 x 495 pli)
Tear	476 x 520 N (107 x 117 lbs force)
Elongation	0.4 x 3.5 %
Transmission	<10%

These properties were determined in accordance with the standards discussed above in connection with Example 1.

A low emissivity layer in the form of an aluminum coating (100-400 Angstroms) was deposited on the topcoat of FEP. The transmission of the final composite was 3.5% and the emissivity of the aluminized face was 0.167.

Figs. 6A and 6B demonstrate the high bonding characteristics of the low emissivity layer to the fluoropolymer deposition layer. Fig. 6A shows a magnified top view (vertical dimension equals 0.56 mm [0.022 inch]) of a portion of the membrane made according to the Example 4 in an unstressed state. In Fig. 6A, the aluminum low emissivity layer covers the warp yarns 40 and fill yarns 43 of the fabric. Fig. 6B shows a magnified top view (vertical dimension equals 0.56 mm [0.022 inch]) directly adjacent to the portion shown in Fig 6A after the membrane has been subjected to a stress load. Fig. 6B demonstrates that the fibrous reinforcement undergoes a reorganization of the warp yarns 40' and fill yarns 43'. Fig. 6B also shows a gap 60 where the aluminum coating covering a fill yarn 43' has cracked due to the stress on the membrane. While the coating has cracked it will nevertheless remain well-bonded to the fluoropolymer-coated yarn.

Although specific forms of the invention have been selected for illustration in the drawings and the preceding description is drawn in specific terms for the purpose of describing these forms of the invention fully and amply for one of average skill in the pertinent art, it should be understood that various substitutions and modifications which bring about substantially equivalent or superior results and/or performance are deemed to be within the scope and spirit of the following claims.

What is claimed is

1. A composite membrane for sound dampening, light transmission and radiant heat control, the composite comprising:

a flexible reinforcement layer;

a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and

a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4

in which the composite membrane is flexible.

2. The composite membrane according to claim 1 in which reinforcement layer comprises a fibrous material having yarns defining an open area of about 30-50%.

3. The composite membrane according to claim 2 in which the low emissivity layer is positioned on the second side of the polymer deposition layer.

4. The composite membrane according to claim 2 in which the low emissivity layer is positioned on the first side of the polymer deposition layer.

5. The composite membrane according to claim 1 in which the flexible reinforcement layer comprises a material selected from the group consisting of poly-(*m*-phenyleneisophthalamide), poly-(*p*-phenyleneterephthalamide), polyurethane elastomeric fiber, polyalkylene, polyamide, polyester, glass fiber, carbon fiber and a blend thereof.

6. The composite membrane according to claim 5 in which the flexible reinforcement layer comprises a fabric of woven fiberglass.

7. The composite membrane according to claim 1 in which the flexible reinforcement layer comprises a non-woven fabric.

8. The composite membrane according to claim 7 in which the flexible reinforcement layer comprises a perforated film.

9. The composite membrane according to claim 1 in which the flexible reinforcement layer comprises multiple strata.

10. The composite membrane according to claim 1 in which the polymer deposition layer comprises a fluoropolymer.

11. The composite membrane according to claim 10 in which the fluoropolymer is selected from the group consisting of polytetrafluoroethylene (PTFE), fluorinated ethylene propylene copolymer (FEP), perfluoroalkoxy resin (PFA), polyperfluorovinylether, polychlorotrifluoroethylene (CTFE), polyvinylidene fluoride (VF2), polyethylenechlorotrifluoroethylene (ECTFE), polyethylene-tetrafluoroethylene (ETFE), polyvinylfluoride (PVF) and blends thereof.

12. The composite membrane according to claim 1 in which the polymer deposition layer comprises a polymer selected from the group consisting of polyvinylchloride (PVC), polyvinylalcohol (PVA) and blends thereof.

13. The composite membrane according to claim 1 in which the polymer deposition layer has a thickness of about 10-50 micrometers.

14. The composite membrane according to claim 11 in which the polymer deposition layer is fire resistant.

15. The composite membrane according to claim 1 in which the low emissivity layer comprises a low emissivity material selected from the group consisting of aluminum, gold, indium tin oxide, chrome brass, copper, nickel, mild steel, stainless steel, lead, platinum, inconel, silver, tantalum, tungsten, germanium, molybdenum, rhodium and blends thereof.

16. The composite membrane according to claim 15 in which the low emissivity layer comprises aluminum.

17. The composite membrane according to claim 15 in which the low emissivity material includes a protective coating of a substance effective to prevent reaction of the low emissivity material with materials in contact with the composite membrane.

18. The composite membrane according to claim 17 in which the substance of the protective coating is a polymeric substance selected from the group consisting of acrylic polymer and polyvinylidene fluoride.

19. An architectural structure comprising a flexible composite membrane for sound dampening, light transmission and radiant heat control, the composite comprising:

a flexible reinforcement layer;

a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and

a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4.

20. The architectural structure of claim 19 having at least one wall, ceiling, dome, window, roof, partition or awning which comprises the flexible composite membrane.

21. The architectural structure of claim 20 in which the flexible composite membrane of the at least one wall, ceiling, dome, window, roof, partition or awning is in a substantially unstressed state.

22. The architectural structure of claim 20 in which the flexible composite membrane of the at least one wall, ceiling, dome, window, roof, partition or awning is under tensile stress of at least about 35 N/cm.

23. A method of controlling sound, light and radiant heat transmission in an architectural structure having component structural members, the method comprising the steps of

(a) providing a flexible composite membrane comprising:

a flexible reinforcement layer;

a polymer deposition layer defining opposite first and second sides, the first side of the polymer deposition layer positioned adjacent to the reinforcement layer; and

a low emissivity layer deposited on at least one side of the polymer deposition layer, the low emissivity layer having an emissivity of less than about 0.4,

(b) deploying at least one component member which comprises the composite membrane.

24. The method of claim 23 in which the at least one component member is a wall, ceiling, dome, window, roof, partition or awning.

25. The method of claim 23 in which the composite membrane is deployed in a liner application of the architectural structure.

26. The method of claim 23 in which the composite membrane is deployed in an outdoor application of the architectural structure.

27. A method of making a flexible composite membrane for sound dampening, light transmission and radiant heat control, comprising: the steps of

providing a flexible fibrous reinforcement layer having yarns defining windows aggregating about 30-50 % of the area of the reinforcement layer,

laminating a polymer deposition layer defining opposite first and second sides to the reinforcement layer such that the first side of the polymer deposition layer is positioned adjacent to the reinforcement layer,

depositing a low emissivity layer having an emissivity of less than about 0.4 onto the first side of the polymer deposition layer, thereby exposing the low emissivity layer through the windows of the polymer deposition layer.

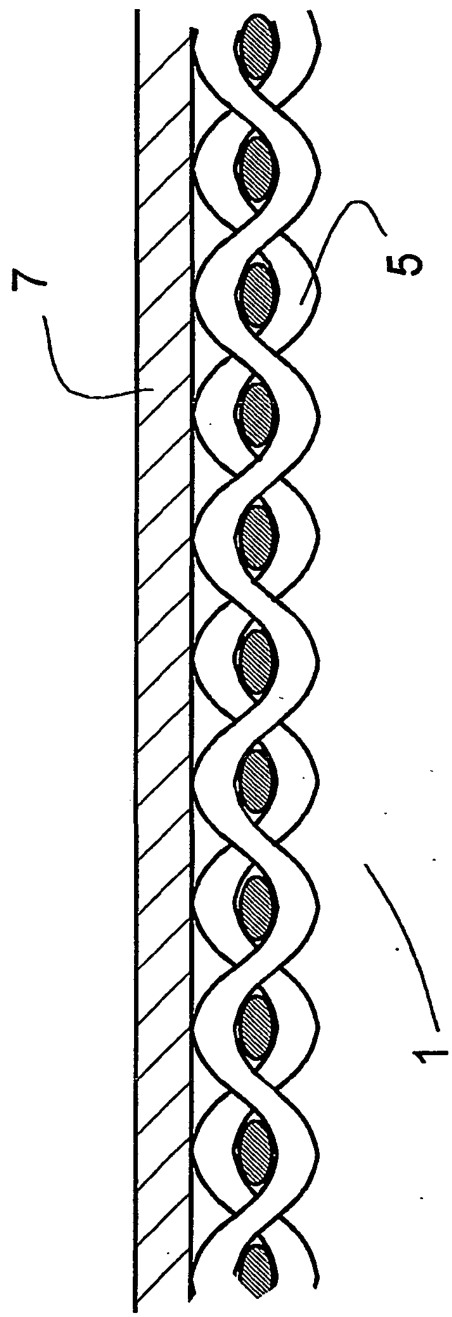

Fig. 1

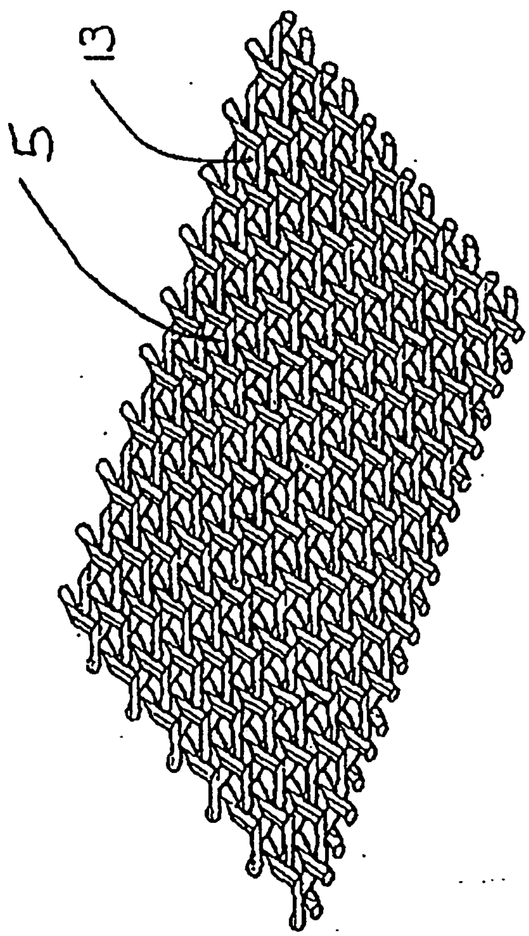

Fig. 2

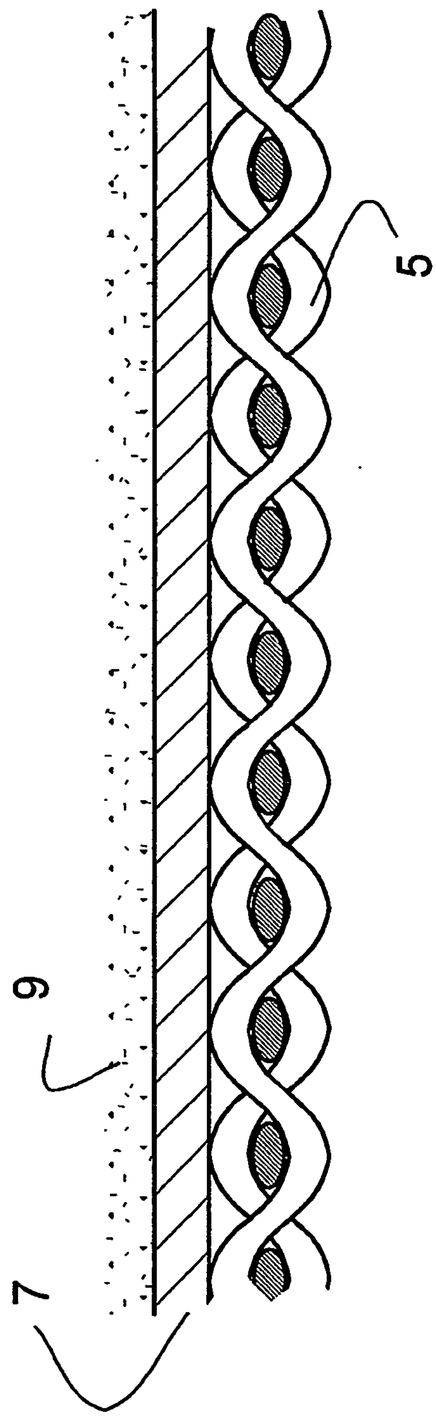

Fig. 3A

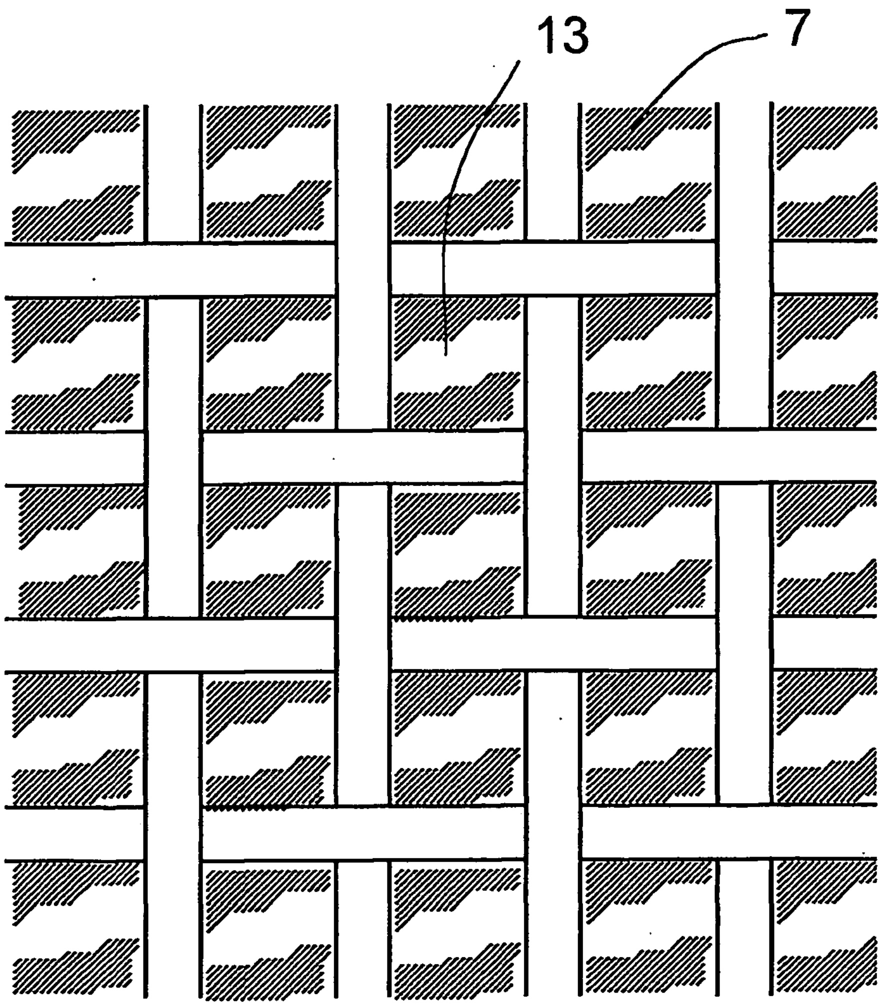

Fig. 3B

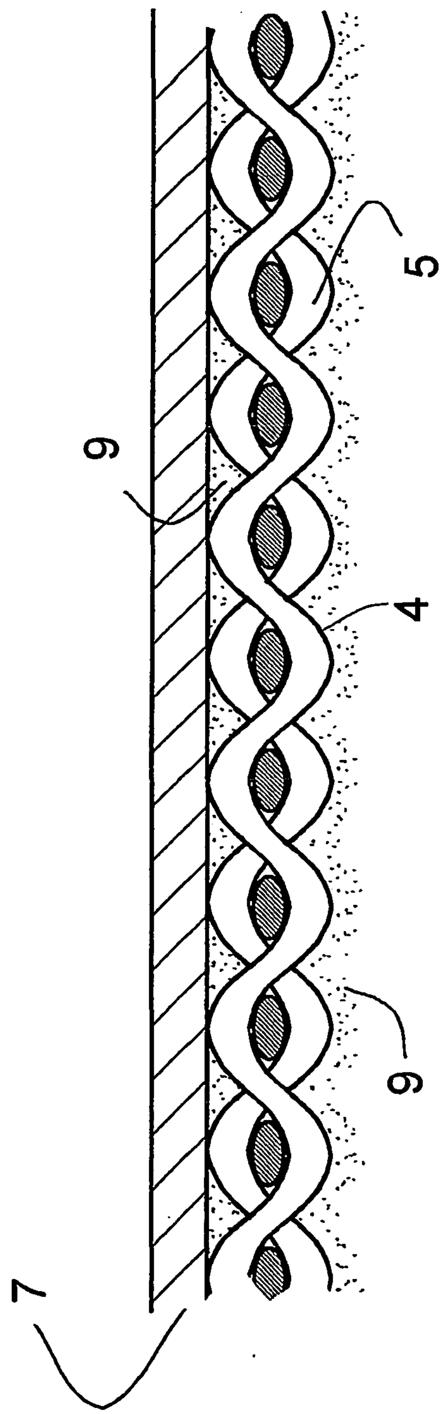

Fig. 3C

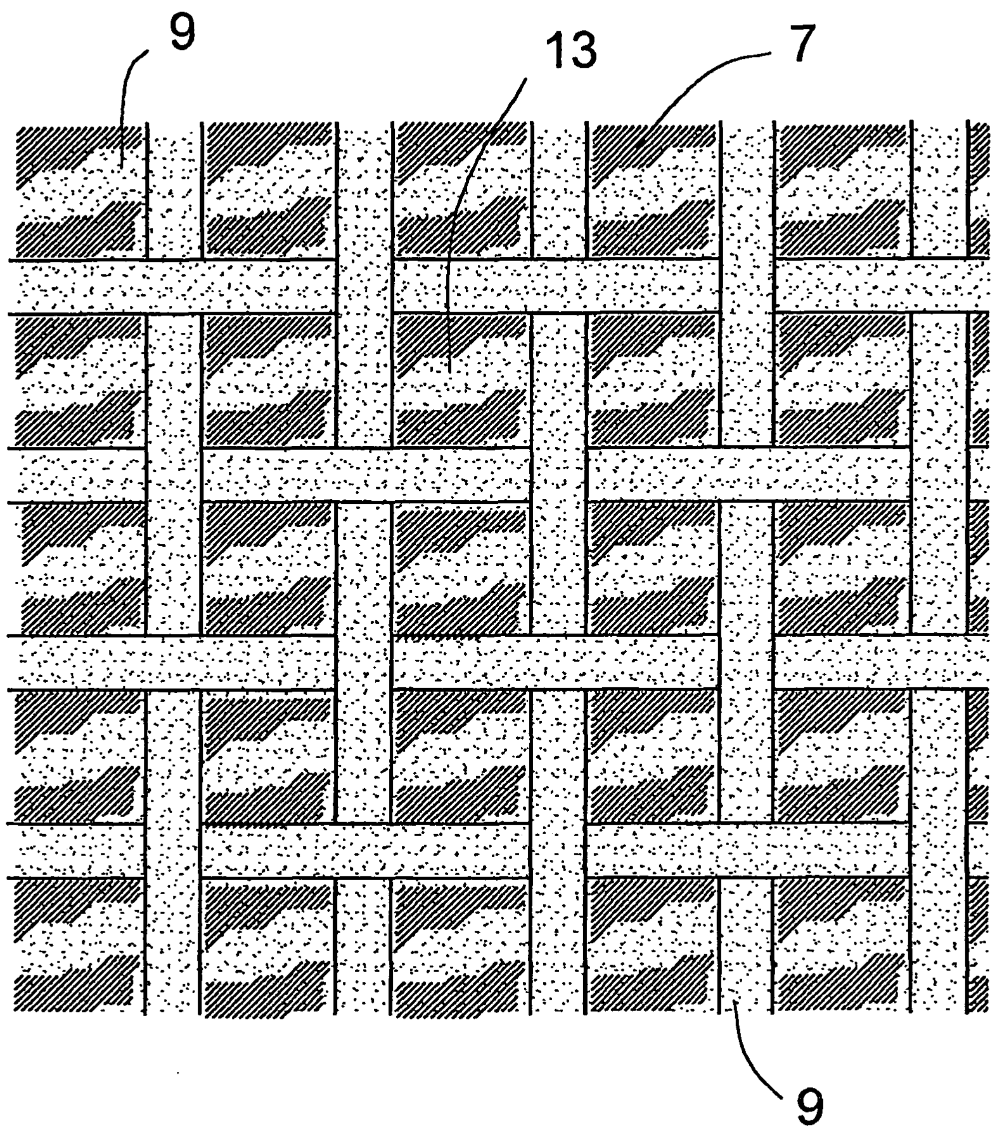

Fig. 3D

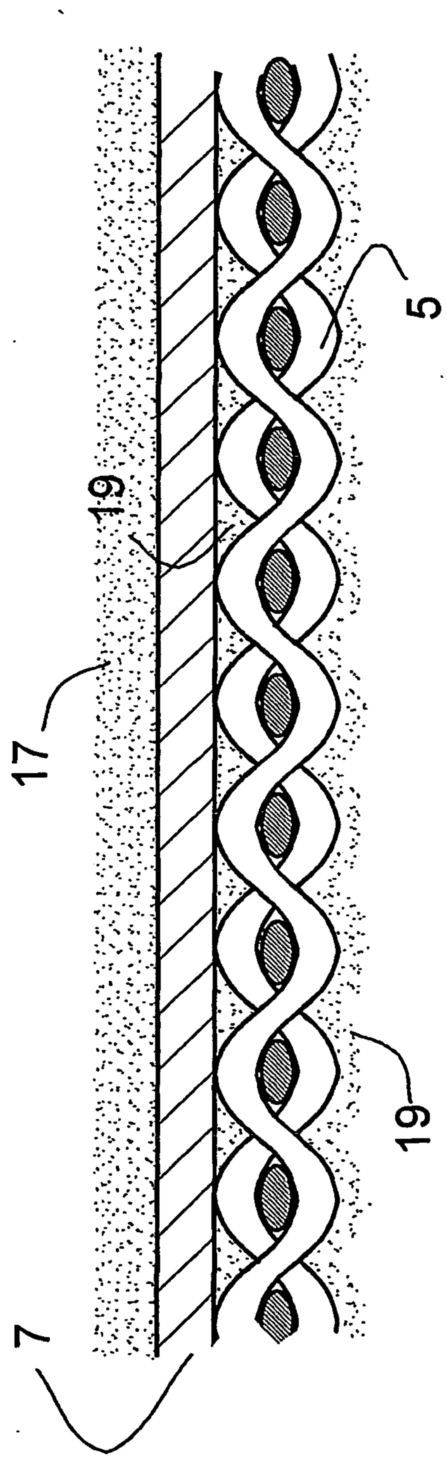

Fig. 4

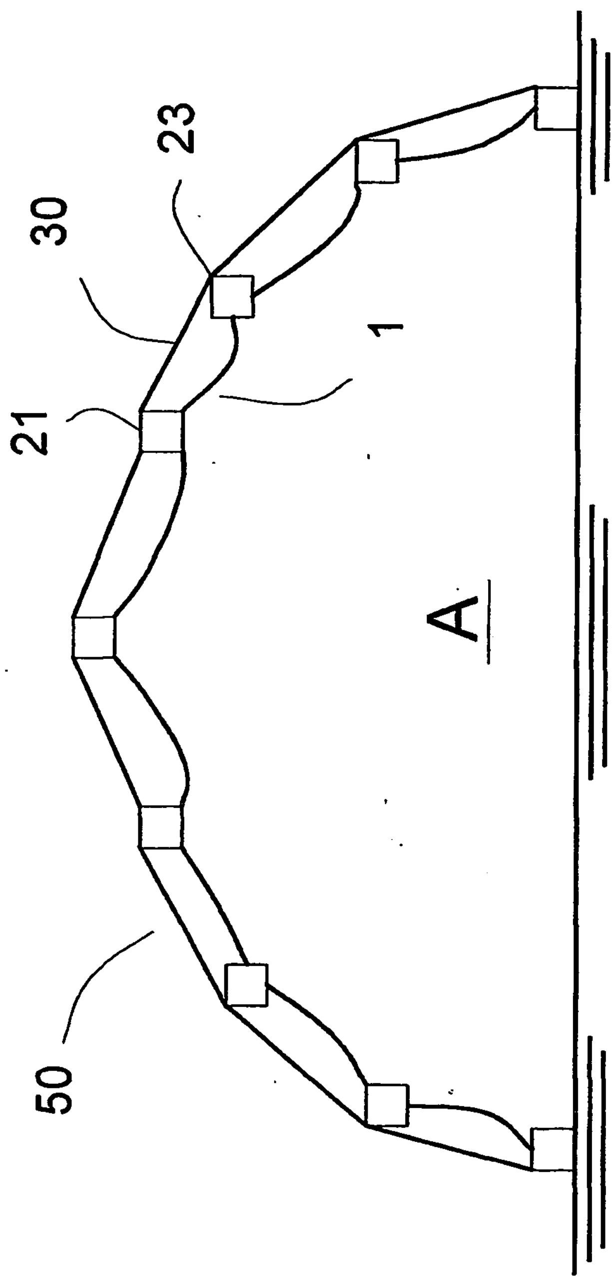

Fig. 5

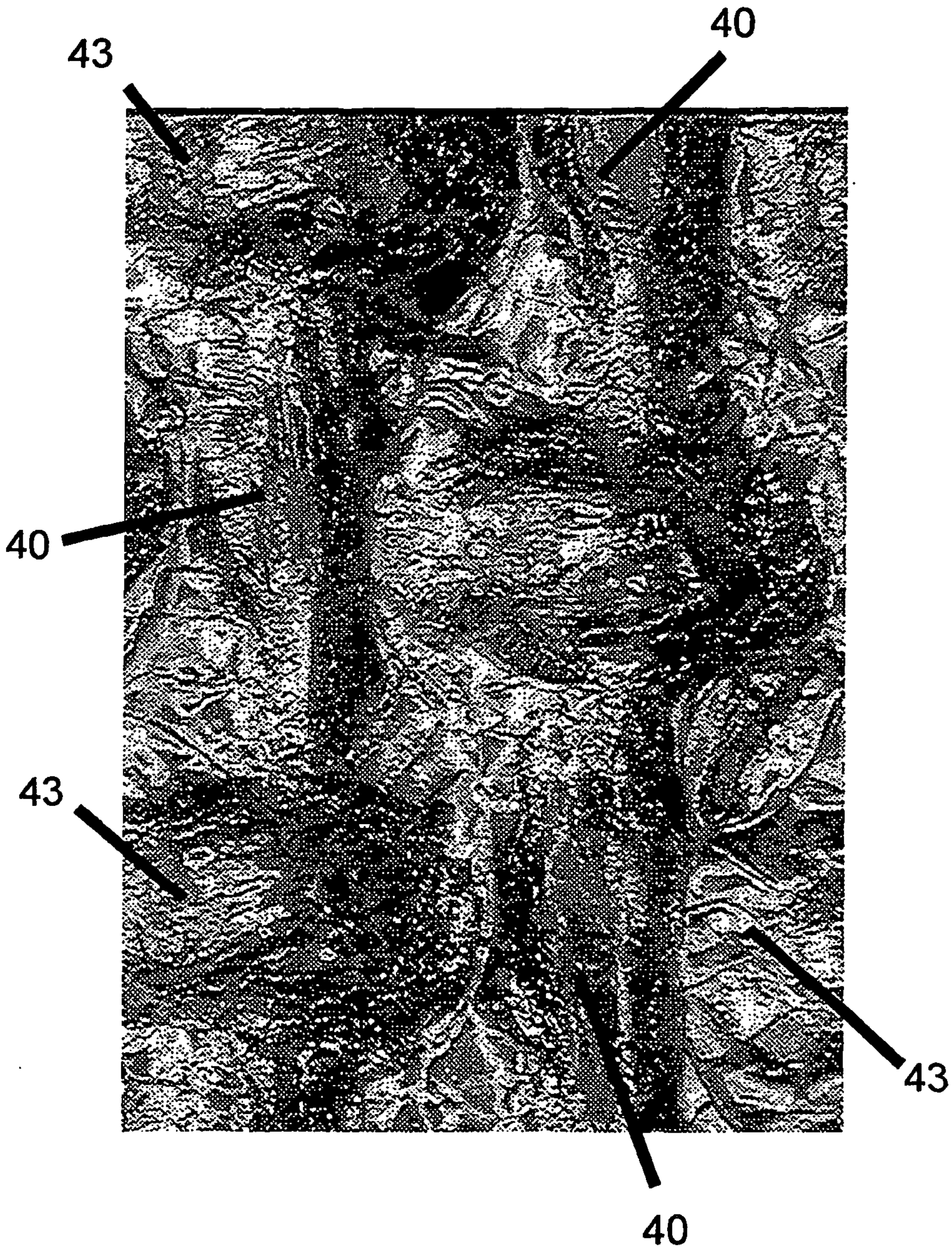

Fig. 6A

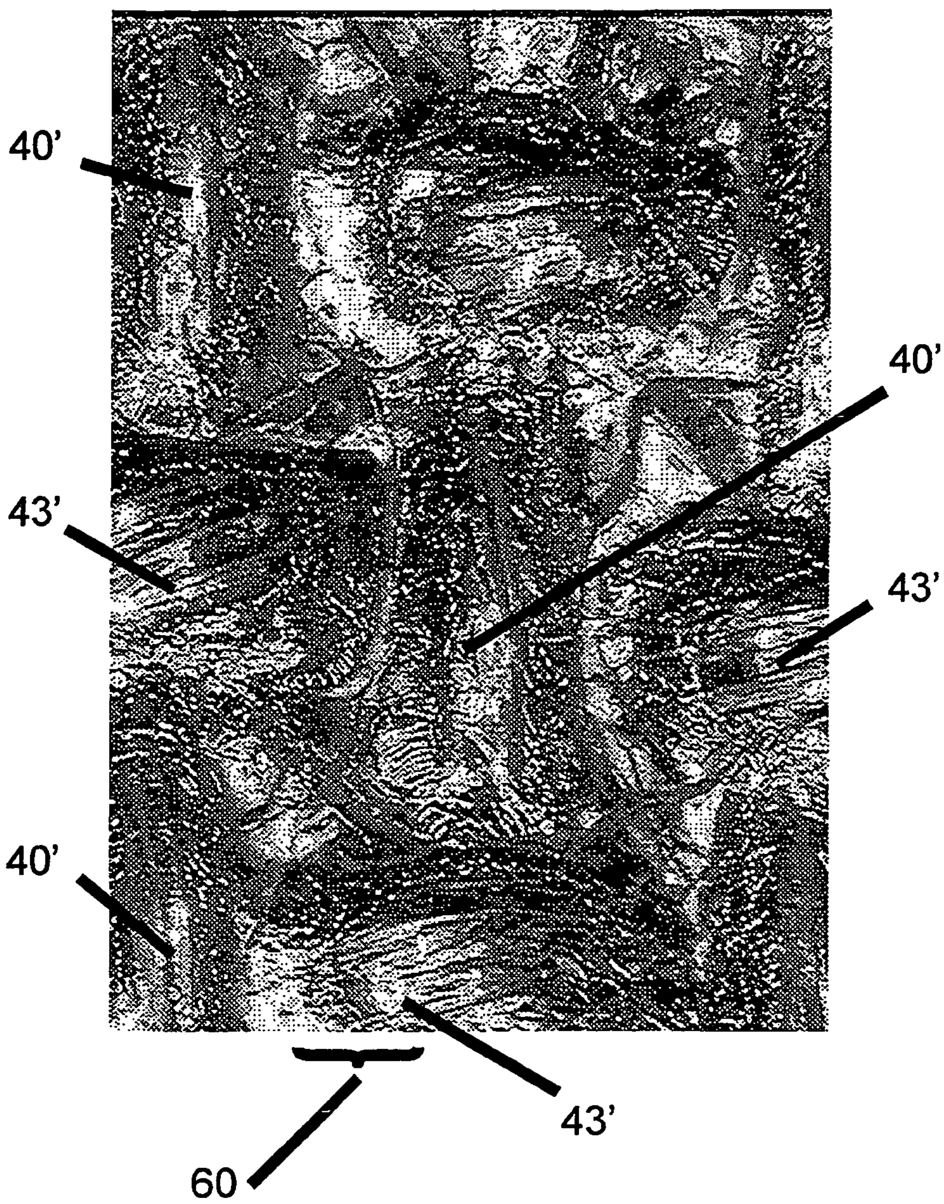

Fig. 6B

INTERNATIONAL SEARCH REPORT

I tional Application No
PCT/US 01/40989

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04H15/54 B32B15/08 B32B33/00 E04B1/74 D06M11/83

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04H E04D B32B E04B D06M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	the whole document	10,11
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A	column 3, line 50 -column 4, line 27; figures 1,2	1
X	US 4 913 978 A (KLOTZ DIETMAR ET AL) 3 April 1990 (1990-04-03) column 3, line 45 -column 4, line 15; figure 1	1,5,6, 13,19-26

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
1 October 2001	09/10/2001

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/40989

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	column 3, line 15 - line 66; figures 1-3	8
Y	GB 1 369 285 A (AMERICAN CYANAMID CO) 2 October 1974 (1974-10-02)	8
A	page 1, left-hand column, line 41 -page 2, right-hand column, line 109; claim 1; figures 1-9	1

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